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Small Earth Dam Failures in the Lomnice River Basin

Ing. Jan Jandora, Ph.D.

The catastrophic flood in August 2002 that attacked a part of the Czech Republic, Austria and Germany, caused breaks of more than 70 ponds in the Czech Republic. The paper is dealing with the analysis of breach of small earth dams located in the south of the Czech Republic in the Lomnice river basin.

Keywords: dam failure, overtopping, numerical modeling

1 Introduction

In August 2002, inhabitants of Bohemia experienced extreme meteorological and hydrological events. On August 6th and 7th and then 11th to 13th, intensive rainfalls occurred in South, West and Middle Bohemia and also in South Moravia. The paper is dealing with the upper part of the Lomnice river basin in South Bohemia (Figure 1) where several small earth dams (ponds) were breached (Table 1). The failures of the dams caused disastrous damages in the villages (Metly, Predmir, Lnare, Tchorovice, etc.) and in the town (Blatna) located downstream of the ponds. Failures of four small earth dams (Melin, Metelsky, Luh and Velký Belcicky - Figures 2-5) were analyzed.

Table 1: The list of breached small earth dams (ponds) in the Lomnice Basin

Breached small earth dam	Dam height [m]	Reservoir volume [10^3 m^3]	Reservoir area [10^4 m^2]
Melin	5.4	350	11.4
Metelsky	7.7	1190	51.4
Podhajsky	2.9	225	15.0
Horejsi	4.0	232	22.4
Dolejsi	2.6	334	30.0
Luh	4.0	120	6.0
Velký Belcicky	6.7	1060	39.4
Pusty	3.5	65	5.5
Buzicky	2.7	900	60.0

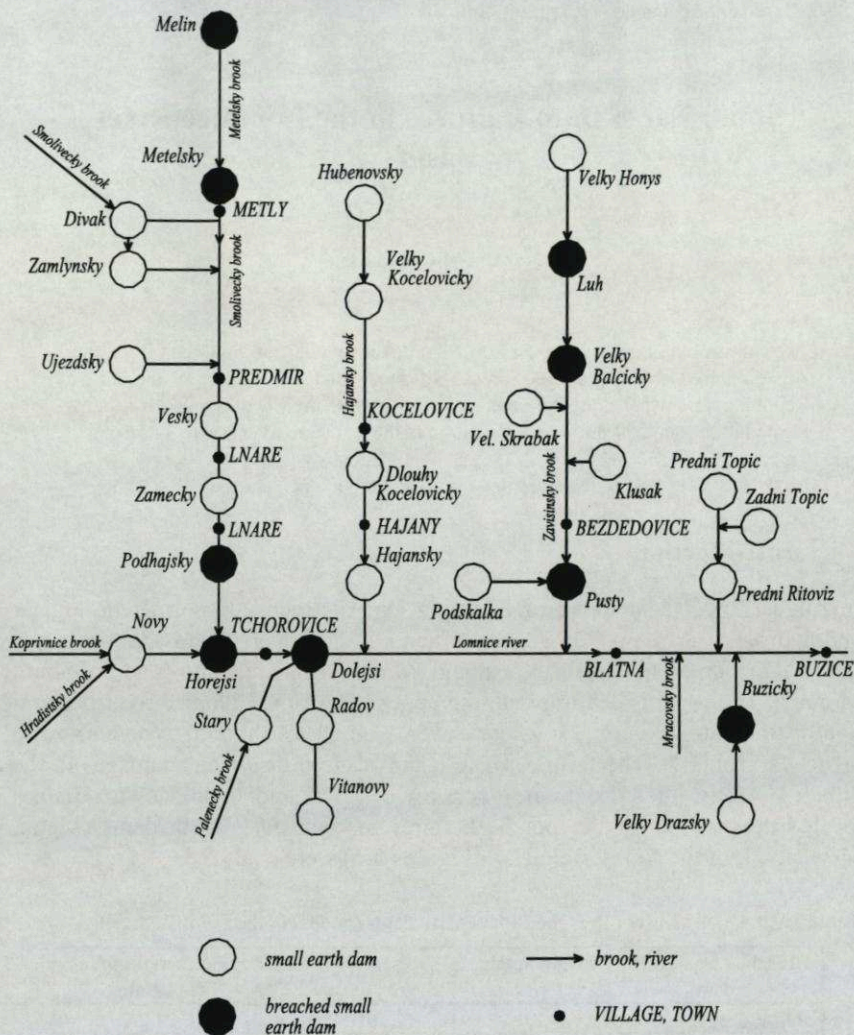


Figure 1: Scheme of the upper part of the Lomnice river



Figure 2: View of the Melin dam breach



Figure 3: One of the two dam breaches of the Metelsky dam



Figure 4: Flow through the Luh dam breach



Figure 5: The Velky Belcicky dam breach

2 Information concerning the studied small dams

The Melin dam is about 5.8 m high. The total spillway capacity is $10.5 \text{ m}^3/\text{s}$ for the water level at the dam crest that is corresponding to 20 years' flood discharge (Q_{20}). The Metelsky dam is about 8.5 m high. The total spillway capacity is $12.0 \text{ m}^3/\text{s}$ for the water level at the dam crest that is corresponding to 20 years' flood discharge (Q_{20}). The Luh dam is about 4.4 m high. The crest of the dam is made from asphalt. The total spillway capacity is $27 \text{ m}^3/\text{s}$ for the water level at the dam crest. 100 years' flood discharge (Q_{100}) is about $19.8 \text{ m}^3/\text{s}$. The Velky Belcicky dam is about 6.3 m high. The total spillway capacity is $27 \text{ m}^3/\text{s}$ for the water level at the dam crest. 100 years' flood discharge (Q_{100}) is about $34 \text{ m}^3/\text{s}$. The dams were breached due to the following effects or with their combination: overtopping, internal erosion and mass movement.

3 Mathematical model and numerical modeling

The problem of dam breach due to overtopping is formulated as initial 1D problem [Jandora, Riha 2002]. Unknown functions are the following:

- $H(t)$ - water surface level in the reservoir measured from datum level;
- $Z(t)$ - bottom level of the breach of the dam body measured from datum level;
- $b(t)$ - width of the breach bottom;
- $v(t)$ - cross-sectional (average) velocity of water in the breach.

To solve these 4 unknown functions we have the following equations at disposal: equation that expresses immediate change of the volume of the reservoir as a function of inflow into the reservoir Q_{in} and outflow from the reservoir Q_s (spillway discharge), Q_o (bottom outlet discharge) and Q_b (breach discharge that is computed as overflow over the broad crested weir):

$$A_s \frac{dH}{dt} = Q_{in} - Q_s - Q_o - Q_b, \quad (1)$$

where A_s is the area of water surface in the reservoir. The remaining equations are state equations that express the relation between:

- velocity $v(t)$ and head over the dam $[H(t) - Z(t)]$:

$$v = \frac{Q_b}{A_b} = \frac{M_b b (H - Z)^{3/2} + M_{bt} s (H - Z)^{3/2}}{b (H - Z) + s (H - Z)^2}, \quad (2)$$

- the rate of change of the bottom level of breach $Z(t)$ and the velocity $v(t)$:

$$\frac{dZ}{dt} = -\alpha_1 v, \quad (3)$$

- the rate of change of the breach width $b(t)$ and the velocity $v(t)$:

$$\frac{db}{dt} = \alpha_2 v, \quad (4)$$

where M_b and M_{bt} are the overflow discharge coefficients for rectangular and triangular weirs, A_b is the cross sectional area of the breach, s is the slope of the side of the breach, α_1, α_2 are empirical coefficients indicating the effect of erosion of the flowing water (Table 2).

The initial conditions are:

$$H(t=0) = H_0; \quad Z(t=0) = Z_0; \quad b(t=0) = b_0; \quad v(t=0) = v_0,$$

where H_0, Z_0, b_0 and v_0 are known values.

Euler method was selected for numerical integration of equations (1-4).

Table 2: Coefficients α_1 and α_2

dam	H [m]	volume [10 ³ m ³]	breach width [m]	max. breach discharge [m ³ /s]	α_1 [1]	α_2 [1]
Melin	5.4	350	17	150	0.003	0.003
Metelsky	7.7	1 190	42 + 30	554	0.003	0.003
Luh	4.0	120	17	58	0.0001*	0.0008*
V. Belcicky	6.7	1 060	42	610	0.0035	0.0035

4 Results

The models were calibrated using data about the process of the flood that had been obtained using reconstruction of the flood events [Jandora, Riha 2004]. Results of simulations, i.e. water surface level in the reservoir, bottom level of the breach, hydrographs of inflow and outflow, are shown at figures 6-9. Maximum breach discharges and average widths of breaches are shown in Table 2.

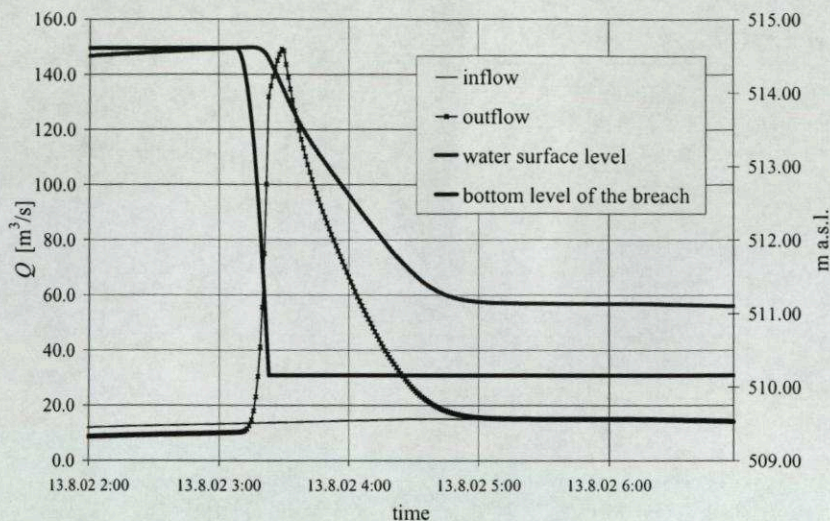


Figure 6: Hydrographs of inflow and outflow, water surface level and bottom level of the breach of the Melin dam

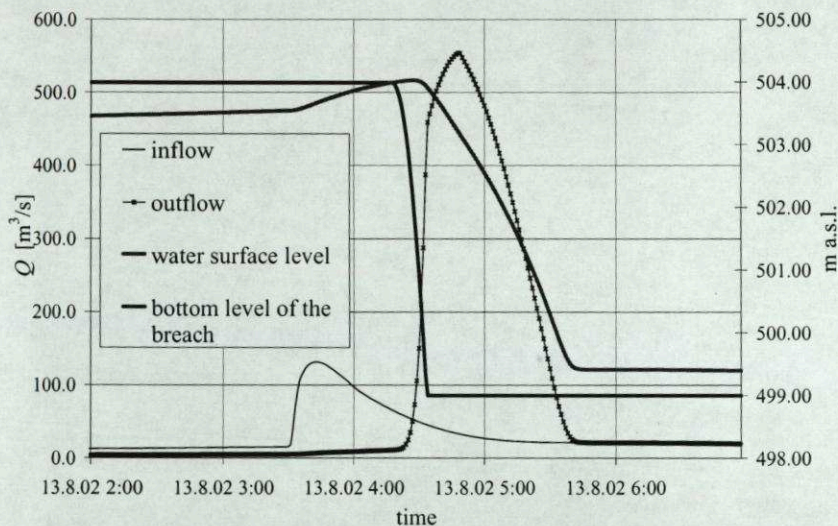


Figure 7: Hydrographs of inflow and outflow, water surface level and bottom level of the breach of the Metelsky dam

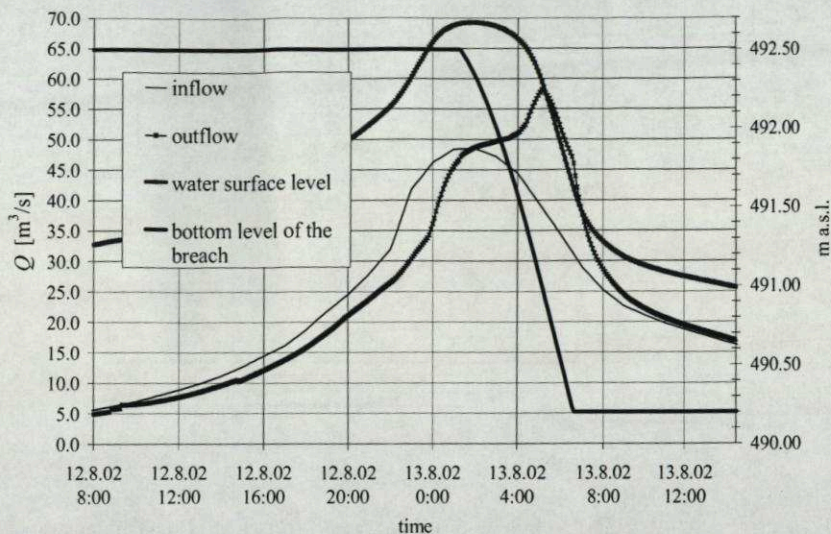


Figure 8: Hydrographs of inflow and outflow, water surface level and bottom level of the breach of the Luh dam

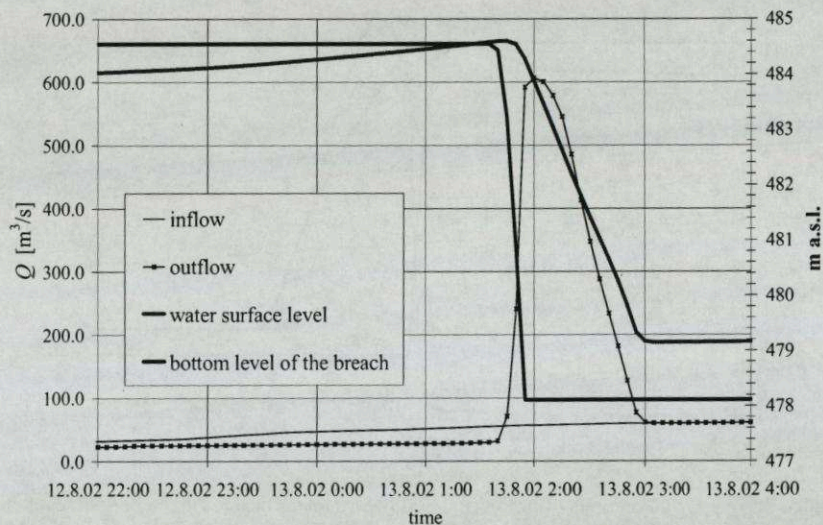


Figure 9: Hydrographs of inflow and outflow, water surface level and bottom level of the breach of the Velky Belicky dam

5 Conclusion

Experience with numerical modeling of breached small dams in the Lomnice river are mentioned in the paper. The calibrations of models were done using data about the reconstruction of the flood events. Values of empirical coefficients α_1 and α_2 indicating the effect of erosion of the flowing water are valuable results of the calibration. In the case of the Luh dam, slower erosion (lower values of α_1 and α_2) was caused by an asphalt road on the dam crest and by relatively small reservoir volume.

The causes of the failures of the analyzed small dams are as follows:

- hydrological situation;
- insufficient spillways capacity;
- in some cases the spillways were blocked by broken gates or clogged racks (Figure 10);
- malfunction of the bottom outlet;
- local slides of the downstream slope;
- action of wind driven waves;
- privileged seepage paths along the wood pipe outlets;
- breaching upstream dam or dams.

6 References

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Figure 10: Spillway of the Luh dam was blocked by clogged racks during the flood

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